U.H.F. field strength measuring receivers

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

UHF FIELD STRENGTH MEASURING RECEIVERS

Report No. K-164

(1963/43)

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SUMMARY

This report describes receivers developed by the Field Strength Section of the BBC Research Department for measuring the field strength of either amplitude or frequency modulated transmissions in the range 470-850 Mc/s. Operational procedure is not discussed.

The receivers are provided with crystal-controlled radio frequency (r.f.) heads and, for convenience, separate heads are used for Band IV and Band V. Two versions of the receiver are described. One, for mobile measurements, is also provided with a calibrating oscillator and a variable attenuator; it can be operated from either internal or external supplies. The other, designed for unattended operation, is mains driven and omits the calibration oscillator and the attenuator. A loudspeaker and amplifier are provided for identifying transmissions.

1. INTRODUCTION

With the introduction of u.h.f. transmissions, the need has arisen for further u.h.f. field strength measuring receivers. The receivers required are of two types, one for general mobile field strength measurements, suitable for recording a wide range of field strengths, and the other a much simpler device, suitable for recording the field strength of signals at a fixed site over a long period of time.

For present purposes, crystal-controlled local oscillators are used in both types of receiver, and the intermediate frequency (i.f.) unit, audio amplifier and power supply are similar to those used in a v.h.f. field strength measuring receiver described in an earlier technical memorandum.[1] It will be necessary to develop a tunable unit at a later date so that transmissions on any frequency within Bands IV and V may be received.

The receivers are housed in 'Minar' cases and make use of transistors throughout, in order to economise in size and weight. The measuring receiver shown in Fig. 1 has internal batteries for up to eight hours operation and is provided with chargers for use on either mains or vehicle 12V d.c. supplies. The recording receiver requires a mains supply to operate it. Two r.f. heads, with appropriate crystals, are used to cover the frequency ranges of 450-600 and 600-850 Mc/s. An intermediate frequency of 10·7 Mc/s is used with a passband of greater than ± 60 kc/s.
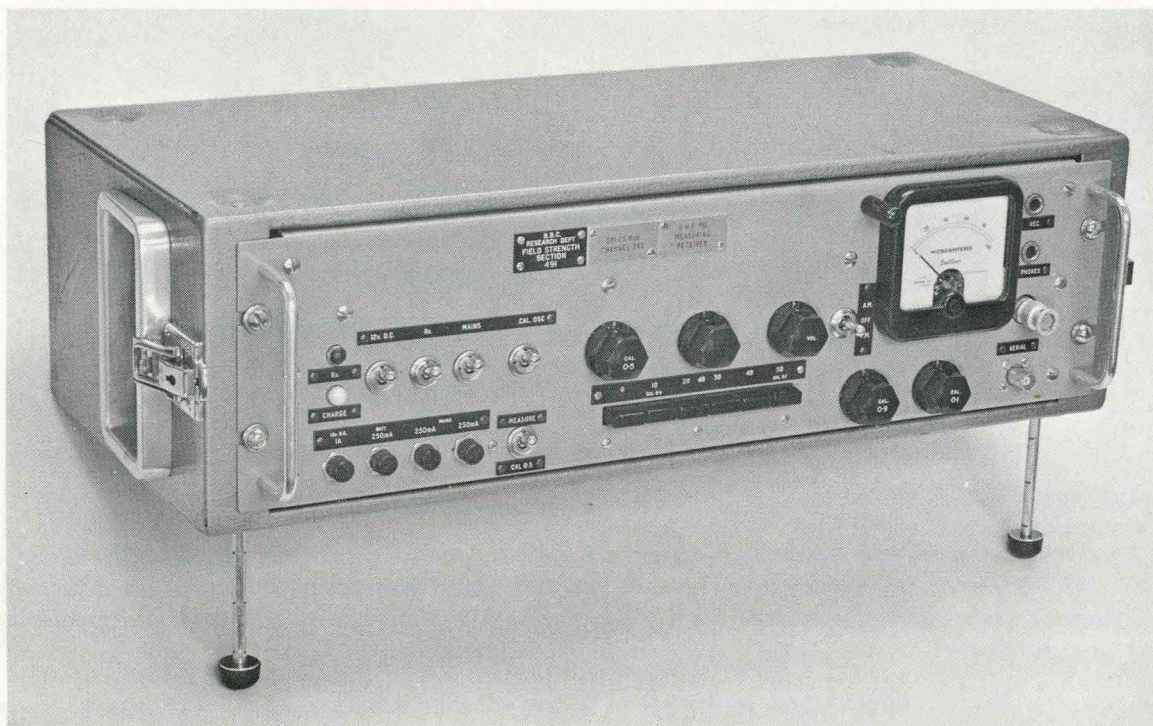
Fig. 1 - Photograph of the measuring receiver

A multiple detection system gives a logarithmic law, over a range of 50 dB, on the output meter. After initial alignment, the multiple detection system seldom requires adjustment other than the standardization of the resistance of the particular recording milliammeter in use. The measuring receiver is provided with a push-button attenuator between the r.f. head and the i.f. amplifier with five steps of 10 dB for extending the range of measurement. It is also equipped with a calibration oscillator which is used to standardize the gain of the receiver. In the recording receiver standard commercial plug-in attenuators are used, so preventing accidental change of receiver sensitivity.

In both receivers separate detectors for amplitude modulated and frequency modulated signals are provided for feeding the loudspeaker amplifier. The sensitivity of the receivers enables signals of $2 \cdot 5 \mu V$ at the receiver input to be recorded.

2. SPECIFICATION OF RECEIVERS

2.1. Frequency Ranges

Crystal-controlled r.f. heads can be provided for any frequency in the range:

Band IV	470-600 Mc/s
Band V	600-850 Mc/s

2.2. Input Impedance

50 ohms unbalanced with a voltage standing wave ratio of better than 0·7.

2.3. Signal Strength Range

(a) For the measuring receiver: From 2·5 μV to 0·15V at the receiver input.

(b) For the recording receiver: From 2·5 μV to 4 mV at the receiver input. (This range may be extended by up to 50 dB by the use of fixed i.f. attenuators.)

2.4. Bandwidth

Frequency, relative to mid-band frequency	Attenuation relative to that at mid-band
± 60 kc/s	< 3 dB
± 600 kc/s	> 60 dB

2.5. Spurious Responses

All spurious responses are attenuated by more than 40 dB relative to the desired signal.

2.6. Intermediate Frequency

10·7 Mc/s.

2.7. Attenuators

(a) Measuring receiver: Five steps of 10 dB are provided between the r.f. head and the main i.f. amplifier.

(b) Recording receiver: Provision is made for the insertion of standard commercial plug-in attenuators in the range 0-50 dB between the r.f. head and the main i.f. amplifier.

2.8. Gain Control

(a) Measuring receiver: A manual gain control is provided for standardizing the gain of the receiver.

(b) Recording receiver: A pre-set gain control is provided for standardizing the gain of the receiver.

2.9. Law of Amplitude Response

The overall amplitude characteristic is logarithmic, with a 50 dB ± 1 dB range, covering the full meter scale. For inputs of less than 10 μV noise will cause an error rising to 2 dB at 2·5 μV. The errors (± 1 dB) in the law include the effects of changes in ambient temperature (-10°C to +45°C).

2.10. Recorder Output

An output for a recording milliammeter 0-1 mA, 3000 ohms is provided, together with a pre-set control to compensate for variations in recorder resistance.

2.11. Audio Output

An internal loudspeaker and a headphone output are provided for use on either amplitude or frequency modulated signals.

2.12. Calibration Oscillator

The measuring receiver is provided with a calibration oscillator which covers a small range around the received frequency. Internal pre-set controls enable this small range to be set anywhere in the appropriate band.

No calibration oscillator is provided for the recording receiver.

2.13. Temperature Range

The performance of the receiver is satisfactory over a temperature range of -10°C to +45°C.

2.14. Power Supplies

(a) Measuring receiver: The internal batteries can supply the receiver for up to eight hours. These batteries are charged or floated from either a 230V 50 c/s supply or an 11·5-15V d.c. supply. The current taken from a 12V d.c. supply is 400 mA when the internal battery is fully discharged and 250 mA when fully charged.

(b) Recording receiver: The power supply required is approximately 3 watts (7VA) 190-260V 50 c/s.

2.15. Dial Light

A meter dial light is provided on the measuring receiver when working on either of the external power supplies.

2.16. Dimensions

Each receiver is housed in a Minar case measuring 21½ × 13 × 6 inches (54·6 × 33·0 × 15·3 cm).

2.17. Weight

(a) Measuring receiver: The overall weight is 30 lbs (13½ kg).

(b) Recording receiver: The overall weight is 27 lbs (12 kg).

3. CIRCUIT DESCRIPTION

3.1. The R.F. Head (Fig. 2)

Two types of r.f. head are provided. These are similar; one covers Band IV and the other Band V. The aerial is coupled to the mixer via a double tuned circuit, access to each tuned circuit being obtained by coupling loops. The coupling between the two circuits is close to critical, the 'loaded Q' of the circuits being about 600. The position of the coupling loops is such as to maintain a reasonably constant coupling over the whole band. The input coupling can be adjusted to give the correct input impedance by rotating the coupling loop.
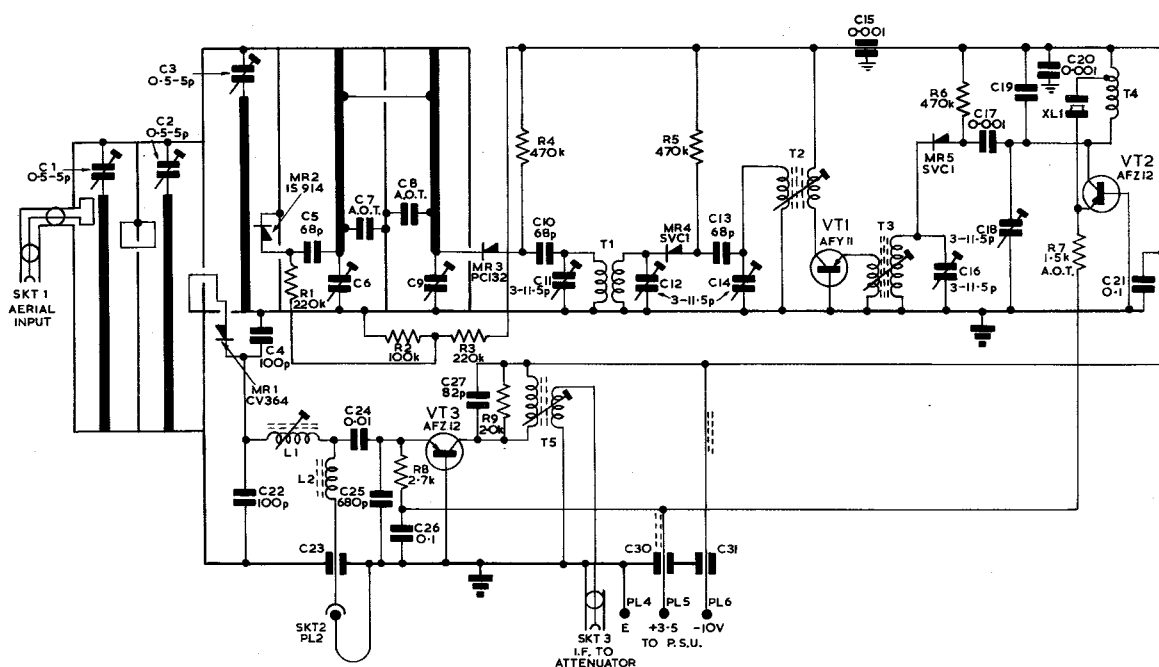

Fig. 2 - The r.f. head

The local oscillator is crystal controlled and consists of an oscillator VT2 using a third overtone crystal. The output from the oscillator is frequency-doubled by a capacity diode doubler MR5 which drives a grounded base amplifier VT1. The output of this amplifier drives three cascaded diode frequency doublers MR4, MR3, MR2, which in turn supply the mixer diode MR1. Double tuned circuits are used between the doublers to reduce spurious harmonic outputs and a high Q (600) line is used as the resonant circuit between the last doubler and the mixer. Tuned lines are also used between the last pair of doublers.

The mixer output is coupled to the emitter of a grounded base i.f. amplifier VT3 by a π network (C22, L1, C25) for impedance matching. This i.f. amplifier provides an output impedance of 72 ohms for the attenuator. Provision is made for measuring the mixer current, using an external meter between PL2 and SKT2.

3.2.   The Attenuator (Fig. 3)

In the measuring receiver the push-button attenuator has five 10 dB sections with a characteristic impedance of 72 ohms.

The recording receiver is used with fixed commercial attenuators up to a maximum of 50 dB.

3.3.   The Intermediate Frequency Amplifier and Detector Unit

The i.f. amplifier and detector unit consists of five main parts, as follows:

(1)   Filter stages

(2)   Logarithmic law stages

(3)   Metering circuits

(4)   A.M. audio amplifier

(5)   F.M. detector and amplifier

3.3.1.   Filter Stages (Fig. 3)

The first i.f. amplifier VT1 is a grounded emitter stage which is used to vary the gain of the whole receiver.   The gain control CAL 0·1 (R86) varies the base potential of emitter-follower VT10.   The consequent change in emitter current of VT1 varies the input impedance, and as VT1 is fed from a low impedance source (approximately 40 ohms), the i.f. current into the base, and hence the output current, will vary with the setting of the gain control.   A total range of 20 dB is obtained.   The resistors R2, R3 form most of the load for the i.f. attenuator and the changes due to the varying input impedance of the amplifier have a negligible effect on the attenuation.

The emitter circuit of VT1 contains a thermistor TH1 which partially compensates for changes in gain of the whole receiver caused by changes in ambient temperature.

The collector circuit of VT1 is transformer-coupled to the following grounded base amplifier VT2.

A quadruple-tuned filter provides the coupling between the second and third amplifier stages.   This filter mainly determines the passband of the receiver.   The two parallel tuned circuits T2, C15, T3, C18 are transformer-coupled to give more convenient component values.   At the output of the filter a series tuned circuit L8, C19 is provided to drive the following grounded base stage VT3.   The filter is matched at its output but mismatched at its input in order to maintain a more constant stage gain.[2]

The amplifier VT3 feeds the 'logarithmic law stages'.   The collector circuit is designed so that the same non-linear input-output characteristic is obtained from all logarithmic law stages.

Fig. 3 - The calibration oscillator, i.f. amplifier and associated circuits

3.3.2. Logarithmic Law Stages (Fig. 3)

The logarithmic law of the i.f. amplifier is derived by a system of multiple detection as described in an earlier report.[3] There are four similar stages VT4-VT7, each with a gain of approximately 17 dB.

In each stage the respective network elements (T5 and L9 in the first stage) feeding the following stage and the detector are in series. The detectors (MR1 in the first stage) have a small delay bias applied to them; this improves the linearity of the logarithmic law by giving a better changeover between the limiting of one stage and the start of output from the following stage. The audio frequency (a.f.) component of the output of the detectors is coupled (by C31 in the first stage) to the a.f. amplifier VT14. The bias for the limiters (MR2 in the first stage) is obtained from the emitter follower VT11.

3.3.3. Metering Circuits (Fig. 3)

The four outputs from the detectors feed into the emitter of the common base amplifier VT13. The low input impedance of this stage minimizes cross coupling between the detectors. The collector current of the amplifier VT13 supplies the meters. At very low input levels the logarithmic law cannot be maintained, so this part of the characteristic is suppressed by the diode MR11 and transistor VT12. This transistor is in parallel with the meter circuit and will attempt to draw a constant collector current irrespective of the collector load. Thus the meter amplifier VT13, a n-p-n transistor, must have a collector current exceeding that of VT12 before any current flows in the meter circuit. The diode MR11 prevents reverse current flowing when the collector current of VT13 is below the limit set by VT12. The full scale reading of the meters may be adjusted by a pre-set control CAL 0·9 (R80). A thermistor (TH2) in series with the meters compensates for changes in the slope of the law with temperature.

3.3.4. A.M. Audio Amplifier (Fig. 3)

The a.m. audio amplifier in the i.f. unit consists of a single grounded base stage VT14 which feeds the main audio amplifier. The purpose of this amplifier is to provide a low impedance termination for the logarithmic-law filter circuits and to give a high output impedance for feeding the main amplifier. Since the audio input has been derived from the logarithmic law circuits, the output is distorted; the resulting sound quality is nevertheless satisfactory for identification purposes.

3.3.5. F.M. Detector and Amplifier (Fig. 3)

Since the signal at the output of the logarithmic law stages has been limited for all except very small input signals, no further limiter is used. A low impedance output from the last i.f. amplifier VT7 supplies a simple discriminator consisting of a pair of series tuned circuits L13, C64, C68, L14. These circuits are tuned respectively to frequencies above and below the intermediate frequency and the outputs from the detectors MR9, MR10 are subtracted to feed the audio amplifier VT8, VT9 via a de-emphasis circuit. The output from VT9 feeds the main audio amplifier.

3.4. The Audio Amplifier (Fig. 3)

The audio amplifier, which may be fed from either the a.m. or f.m. detectors, consists of a driver stage VT16 and a complementary-symmetry class B output stage VT17 and VT18. Feedback from the output to the base of the input stage stabilizes the d.c. working conditions of the amplifier. The a.c. feedback in this circuit is limited by R100, C98. The emitter resistor R97 gives additional feedback to the driver amplifier VT16, thereby raising its input impedance.

The two emitter follower output amplifiers VT17, VT18 are biased for optimum standing current by R96, MR14, to minimize distortion. The diode MR14 provides some temperature compensation for the bias. The a.c. feedback from the output to a tap on the collector load of VT16 ensures that the output transistor VT17 may be driven to bottoming and also maintains an almost constant current in the collector circuit of the driver VT16. This improves the linearity of the stage and reduces cross-over distortion caused by variations in the input impedance of the transistors (VT17, VT18) near cut-off. The output drives a high impedance (80-ohm) loudspeaker or headphones.

3.5. The Calibration Oscillator (Fig. 3)

The calibration oscillator, used only in the measuring receiver, consists of a grounded base oscillator VT15 covering the range 155-215 Mc/s on pre-set controls. A trimmer C83 on the front panel gives fine adjustment of frequency. The output of the oscillator is frequency-multiplied by the capacity diode MR12. A frequency-tripler is used for Band IV, and a frequency-quadrupler is used for Band V. The output from the multiplier is monitored by a backward diode MR13 metering circuit and is also attenuated by a capacity attenuator (C93, C94) which is pre-set for the standard output. The attenuator, via C95, R92, supplies the calibration output lead which replaces the aerial during calibration. The output of the oscillator is set to give a standard output by varying the current through the oscillator by means of the variable resistor R88 in the emitter circuit of VT15. Frequency drift due to temperature is compensated by the 'Tempatrimmer' C82.

4. POWER SUPPLIES

4.1. The Measuring Receiver (Fig. 3)

In the measuring receiver the main power supply for the receiver is a re-chargeable 19·5V nickel-cadmium battery BY2 of 900 mAH capacity, with alternative charging facilities from either 250V a.c. 50 c/s or 12V d.c. supplies. Stabilized outputs from the battery supply the receiver. Since a normal dial lamp on the receiver would take as much current as the rest of the unit and so halve the life of the battery, a flashing light is used. A dial light is provided for the meter when external supplies are used.

4.1.1. Mains Charger (Fig. 3)

The battery charger operates from a 190-260V 50 c/s mains supply and uses a simple transformer and bridge circuit MR24-MR27 to give a d.c. supply to the charge regulator VT29. The regulator consists of an emitter follower with the battery in its emitter circuit and its base supplied from a Zener diode chain MR20-MR22.

When the battery is fully charged, the potential of the emitter of the transistor VT29 will be very close to its base potential and the charge rate will be very low. A small fall in battery voltage will cause a large current to flow in the transistor. This current is limited by the collector load (R123 in parallel with ILP2) of the regulator transistor VT29. The transistor will bottom when the current becomes excessive and thus limit the charge rate. The brilliance of the lamp (ILP2) in the circuit gives an indication of the charge rate. A diode MR23 is included in series with the battery to prevent reverse current discharging the battery when the charger is not in use.

4.1.2. 12V D.C. Charger (Fig. 3)

A converter is used to step up the nominal 12V vehicle battery to a value sufficient to charge the 19·5V battery in the receiver. The converter consists of a square wave oscillator VT30-31. The output of this oscillator uses a bridge rectifier MR26-MR29 to supply the same charge regulator as the mains charger. A diode MR31 prevents damage to the converter in the event of a reversed polarity supply being connected to the receiver.

4.1.3. Stabilizer Circuit (Fig. 3)

A conventional series stabilizer VT21-VT24 is used to stabilize the main 13·5V output. The collector load of the control amplifier VT23 consists of a n-p-n transistor VT24 run under constant current conditions. This current is determined by its base potential, the forward drop of the silicon diode MR18 and also by the emitter resistor R110. This constant current load for VT23 ensures a high gain for this stage and a very good reduction of mains ripple fed into the series stage VT21-VT22.

If, due to a fault, the current in the output transistors VT20 and VT21 becomes excessive, the voltage drop across the common collector load R105 will cause the diode MR17 to conduct and cut off the constant current stage VT24, thus limiting the output.

The Zener diodes MR15-MR16 in the emitter circuit of the control amplifier VT23 also provide an output for the emitter follower VT19. The emitter of VT19 is earthed and provides the reference point for the whole supply which has outputs of +3·5V and -10V relative to earth. A further emitter follower VT20 gives a separate -9·8V output for the audio amplifier and flasher unit. This separate output prevents the varying currents of the class B audio amplifier from altering the main receiver potentials.

The nickel-cadmium batteries used in the measuring receiver suffer from the disadvantage of being destroyed if the polarity of a single cell is reversed; this might occur when the battery is over-discharged. To minimize this trouble, a safety circuit is used. In this circuit a small nickel-cadmium battery BY1 is maintained in a fully charged condition by R114, MR19. This battery has, when fully charged, a voltage equal to the minimum safe voltage of the main battery BY2. The difference between the two battery voltages maintains the grounded base transistor VT25 in a cut-off condition. If, however, the main battery voltage falls below that of the safety battery, the transistor VT25 will conduct and rapidly cut off the series transistors VT22 and VT21 of the stabilizer. This reduces the load to that of the safety transistor VT25. The batteries can supply this load for several days before falling to the potential where the batteries are damaged.

4.1.4. Flasher Circuit (Fig. 3)

This circuit is incorporated only in the measuring receiver.

It has been found advisable to have some easily visible indication that the receiver is switched on. A normal low-consumption lamp takes as much current as the rest of the receiver, thus halving the life that can be obtained from the internal battery. To overcome this problem a flasher circuit is used. This circuit produces a 150 msec flash every second, and is quite as noticeable as a normal lamp. The peak current (4 mA) drawn from the supply is less than 1/10 of that of a lamp. Some of this current saving is obtained from the effective voltage transformation of the supply, a 6V lamp being used with a 13·5V supply. The oscillator consists of a Schmitt trigger circuit VT26 and VT28 with widely spaced triggering potentials. The transistor VT28 is normally conducting with VT26 cut off, so cutting off the amplifier VT27. The capacitors C102-C104 slowly charge until the potential across them reaches approximately 12V; the trigger circuit then operates and VT28 cuts off whilst VT26 conducts. This drives VT27 hard into conduction and discharges the capacitors C102-C104 through the lamp ILP1. When the capacitors have discharged to about 2V the circuit triggers in the reverse direction and restores the circuit to its original condition. The discharge current does not flow through the supply and thus produces very little disturbance to the power supplies.

4.2. The Recording Receiver (Fig. 4)

The main transformer supplies a bridge rectifier MR24-MR27 which is followed by a preliminary stabilizer, an emitter follower VT29 whose base potential is determined by the Zener diodes MR20-MR22. The preliminary stabilizer supplies the main stabilizer which is identical to that of the measuring receiver except for the omission of the safety battery and transistor VT25.
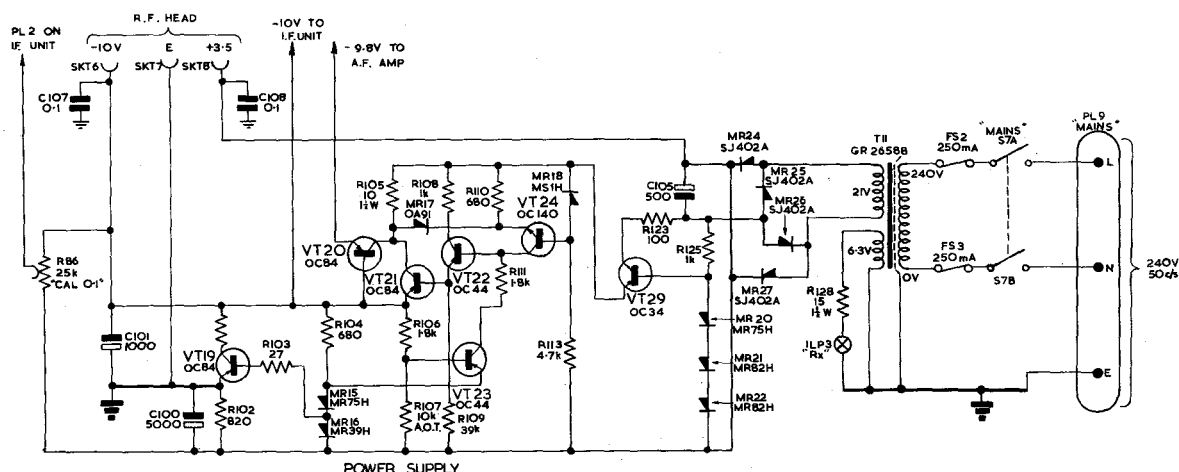

Fig. 4 - Power supplies for the recording receiver

5. REFERENCES

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